**Exploring the Environment**

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**Problem-Based Learning**   
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**Goals & Objectives  
Problem-Based Learning Defined:** Finkle and Torp (1995) state that "problem-based learning is a curriculum development and instructional system that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem solvers confronted with an ill-structured problem that mirrors real-world problems" (p. 1). Specific tasks in a problem-based learning environment include:

* determining whether a problem exists;
* creating an exact statement of the problem;
* identifying information needed to understand the problem;
* identifying resources to be used to gather information;
* generating possible solutions;
* analyzing the solutions; and
* presenting the solution, orally and/or in writing.

**Short Cut to Problem-Based Learning:** This is a simplified model. Note that it is an iterative model. Steps two through five may be conducted concurrently as new information becomes available and redefines the problem. Step six may occur more than once--especially when teachers place emphasis on going beyond "the first draft."

**1.** Present the problem statement. Introduce an "**ill-structured**" problem or scenario to students. They should not have enough prior knowledge to solve the problem. This simply means they will have to gather necessary information or learn new concepts, principles, or skills as they engage in the problem-solving process.

**2**. List what is known. Student groups list what they know about the scenario. This information is kept under the heading: "What do we know?" This may include data from the situation as well as information based on prior knowledge.

**3**. Develop a problem statement. A problem statement should come from the students' analysis of what they know. The problem statement will probably have to be refined as new information is discovered and brought to bear on the situation. Typical problem statements may be based on discrepant events, incongruities, anomalies, or stated needs of a client.

**4**. List what is needed. Presented with a problem, students will need to find information to fill in missing gaps. A second list is prepared under the heading: "What do we need to know?" These questions will guide searches that may take place on-line, in the library, and in other out-of-class searches.

**5**. List possible actions, recommendations, solutions, or hypotheses. Under the heading: "What should we do?" students list actions to be taken (e.g., questioning an expert), and formulate and test tentative hypotheses.

**6**. Present and support the solution. As part of closure, teachers may require students to communicate, orally and/or in writing, their findings and recommendations. The product should include the problem statement, questions, data gathered, analysis of data, and support for solutions or recommendations based on the data analysis.

Students are encouraged to share their findings on-line with teachers and students in other schools, within the district, region, state, nation, or internationally. Teachers will find that students pay more attention to quality when they have to present or show their written products to students in other schools.

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| --- | --- | --- |
| Adapted from Stepien, Gallagher, & Workman, 1993 | | |
| **What do we know?** | **What do we need to know?** | **What should we do?** |
| .. | .. | .. |

**Review of research**: (1) learning in a PBL format may initially reduce levels of learning (this may be due to the difficulty in determining what students learned using traditional competence measures), but may foster, over periods up to several years, increased retention of knowledge; (2) some preliminary evidence suggests that PBL curricula may enhance both transfer of concepts to new problems and integration of basic science concepts into clinical problems; (3) PBL enhances intrinsic interest in the subject matter; and (4) PBL appears to enhance self-directed learning skills (metacognition), and this enhancement may be maintained (Norman & Schmidt).

**Goals of PBL**: PBL is used to engage students in learning. This is based on several theories in cognitive theory. Two prominent ones are that students work on problems perceived as meaningful or relevant and that people try to fill in the gaps when presented with a situation they do not readily understand. Teachers present students with a problem set, then student work-groups analyze the problem, research, discuss, analyze, and produce tentative explanations, solutions, or recommendations. It is essential to PBL that students do not possess sufficient prior knowledge to addressing the problem. In the initial discussion, students develop a set of questions that need to be addressed. These questions then become the objectives for students' learning.

Norman and Schmidt (1992) state there are three roles for PBL. The first is the acquisition of factual knowledge, the second is the mastery of general principles or concepts that can be transferred to solve similar problems, and third, the acquisition of prior examples that can be used in future problem solving situations of a similar nature.

**Acquiring Factual Knowledge:** Activation of prior knowledge facilitates the subsequent processing of new information. Small group discussion helps activate prior knowledge.

Elaboration of knowledge at the time of learning enhances subsequent retrieval.

Matching context facilitates recall. This means that retrieval of information is facilitated by retrieving under the same conditions in which the information was learned.

Transfer of Principles and Concepts: to insure successful transfer

First, students need to get the problem cold. Any advance organizer that identifies the problem in advance appears to detract from the PBL process. It appears important that students learn and acquire concepts while wrestling with the problem.

Feedback: The problem solver must receive corrective feedback about the solution immediately upon completion **Note**: feedback may vary depending upon the situation. Some problems may be convergent; others may allow multiple correct solutions.

**Resources for Learning**: The Exploring the Environment™ (ETE) materials have enough information to get students started with the problem set. Background information is provided, but we have purposely avoided duplicating everything available about a given subject. Within the World Wide Web and other Internet features is a seemingly infinite amount of information. In some cases, the ETE modules point students to additional areas. Often, students will have to conduct Internet and Web searches to find materials. Teachers should avoid having a group of three to five students rely only on the electronic or on-line materials. Students must be encouraged to divide the work through a delegation of tasks. Some students may be working with the computer while others are finding or using written references, seeking out and interviewing experts, or using other audiovisual aids.

Activation of prior knowledge, taking place while a problem is initially discussed, may have a stage-setting function for new knowledge that facilitates students processing it.

**Actual Steps**: Have the students discuss the scenario, listing everything they know under a heading entitle: "What we know." This process helps activate and elaborate prior knowledge, which is subsequently used for the comprehension of new information.

**Creating the ill-structured Problem:** (Adapted from Stepien, Gallagher, & Workman, 1993).

**1.** Students need more information than is initially presented to them. Missing information will help them understand what is occurring and help them decide what actions, if any, are required for resolution.

**2.** There is no right way or fixed formula for conducting the investigation; each problem is unique.

**3.** The problem changes as information is found.

**4.** Students make decisions and provide solutions to real-world problems. This means there may be no single "right" answer.

**Problems in Implementing PBL:   
Students:** Students familiar with the traditional "talk and chalk" classroom are likely to be uncomfortable with the PBL format for some time. It will be up to the teacher to convince students that they are researchers looking for information and solutions to problems that may not have one "right answer." Here are likely problems:\* Students will want to know what they really have to do to get their grade. They will expect the teacher to prescribe a number of tasks, events, concepts, and a set "number of pages" for written products.

Those students adept at "book learning" may feel uncomfortable in PBL roles in which they have to conduct research, coordinate with peers, and generate unique products. These students' parents may express some concern when their son or daughter isn't comfortable with this new environment.

**Ownership**. Students must feel that this is their problem, otherwise they'll spend their time figuring out and delivering exactly what the teacher wants.

**Teachers:** Teachers unfamiliar with PBL are in for some surprises. Moving into "untraditional" instructional modes may appear risky, scary, and uncertain. If students are new to PBL, they may actually learn less at first. Becoming comfortable with PBL will take at least a year, perhaps more, and this mode will consume more of the teacher's energy. The good news is that this environment is exhilarating, meaningful, and rewarding. It may turn out to be one of the most exciting things teachers have experienced.

**Relevance**. Look for windows into students' thinking in order to pose problems of increasing relevance.

**Challenge**. The problem scenario should challenge students' original hypotheses. We have tried to make the Exploring the Environment modules engaging; don't hesitate to elaborate upon the scenario to engage students.

**Time**. Students must be given time and stimulation to seek relevance and the opportunity to reveal their points of view.

**Ownership.** If the teacher appears to be heading students in a particular direction, they'll see that this really isn't their problem after all. They'll see that there is a correct solution and that it belongs to the teacher.

**Complexity**. Teachers new to the PBL classroom may be tempted to give students key variables, too much information, or problem simplification. Complexity of scenarios has been shown to increase student motivation and engagement.

**Second questions**. Avoid using the dreaded "second question" as a signal the student is wide of the mark. Regularly asking students to elaborate sends the message that the teacher wants to know what the student thinks and why. Brooks and Brooks (1993) state that "awareness of students' points of view is an instructional entry point that sits at the gateway of personalized education...teachers who operate without awareness of their students' points of view often doom students to dull, irrelevant experiences, and even failure" (p. 60).

**Note:** Questioning Techniques. In a PBL classroom, teachers should act as metacognitive coaches, serving as models, thinking aloud with students and practicing behavior they want their students to use (Stepien and Gallagher, 1993). Students should become used to such metacognitive questions such as: What is going on here? What do we need to know more about? What did we do during the problem that was effective? Teachers coax and prompt students to use questions and take responsibility for the problem. Over a period of time, students become self-directed learners, teachers can then provide less scaffolding, fading into the background (Stepien and Gallagher, 1993).

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**Problem-Based Learning Background & Objectives  
A Primer for Teachers Using the Exploring the Environment**™ **Modules** Education's purpose includes preparing people to lead fulfilling and responsible lives. Science education should help students understanding the biophysical environment and human interaction with that environment. Such understanding should lead to informed decisions concerning how humans treat their life-support system, the biosphere (AAAS, 1990).

Our project, Exploring the Environment (ETE), is developing earth science modules for delivery over the Internet. Technology, such as remote sensing, simulations, and ground-truthing provide us with a myriad of tools with which to study global-scale interactions and to make informed predictions and decisions about our planet. Remote sensing allows students to see Earth subsystem interrelations on a grand scale. It is ideal for the study of change and of the wider relations between components of the biosphere. Before remote-sensing technology became available, it was difficult for humans to realize the global impact of their actions. With the advent of remote-sensing capabilities it became evident that the interconnectedness of Earth systems, however, means that human-induced changes are seized upon and magnified by nature, to be passed through the chain of natural events, to have far-reaching, and sometimes, unexpected effects.

These tools, however, seem to be making little impact in elementary and secondary schools (Cuban, 1986). Studies show that science learning at the high school level has little effect upon students' science literacy, including their understanding of basic concepts, the process of science, or the impact of science on society (Miller, 1986). Our experience and research indicate that change in science classroom methodology can lead to student understanding of critical issues. Our goal is to engage and motivate students to explore and understand issues in depth. The challenge is to provide teachers with alternative approaches to teaching and learning that will achieve the goal. Problem-based learning (PBL) is one of these alternatives.

**Problem-Based Learning** Finkle and Torp (1995) state that "problem-based learning is a curriculum development and instructional system that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems" (p. 1). What is desired is a real-world program that combines science content and skills to create useful experiences for learners by drawing connections between students' lives and the Earth's interacting environmental subsystems and environmental resource issues. The benefits of PBL include engagement in learning due to cognitive dissonance, relevance to real-world scenarios, opportunities for critical thinking, metacognitive growth, and real-world authenticity that promotes transfer and recall (Finkle and Torp, 1995).

Remote Sensing Datasets in the ETE modules will provide the major source of information for students' problem solving initiatives. The core of problem-solving is to learn to use information in a logical, useful way. The only real purpose to gather information is to use it (Glasser, 1993)! These data are derived from real-world remote-sensing tools, employed by practicing scientists and accessed through the Internet. A very simple design of events for PBL comes from Stepien, Gallagher, and Workman (1993). In their iterative model, students are presented with an ill-structured scenario. Team of students then pool information and list it under a heading "What do we know?" They evoke prior knowledge and discuss the current situation. This analysis leads to a problem statement. Although the problem statement is sometimes misdirected, it is a starting point and may be revised as assumptions are questioned and new information comes to light. Under the heading "What do we need to know?" students list questions that must be answered to address missing knowledge or to shed light on the problem. Under a third heading, "What should we do," students keep track of such issues as who to interview, what resources to consult, or what specific actions to perform. Students gather information from the classroom, through electronic sources, the school's library, and from experts on the subject. As new information comes to light, it is analyzed for its reliability and usefulness in either refining working hypotheses or articulating the problem statement.

It is important to train teachers to adopt new frameworks for the classroom when operating in PBL environments. For example, students begin the problem cold. They discuss the problem, generate hypotheses, identify relevant facts, and learning issues. Unlike standard classes, learning objectives are not stated up front. Students generate the learning issues or objectives based on their analysis of the problem. If prerequisite knowledge relevant to the problem's resolution is missing, then students are responsible for its accumulation (Savery and Duffy, In Press).

**Design** Savery and Duffy (In Press), discuss issues for instructional design in constructivist environments:

* Anchor all learning activities to a larger task or problem.
* Support the learner in developing ownership for the overall problem or task.
* Design an authentic task.
* Design the task and the learning environment to reflect the complexity of the environment students should be able to function in at the end of learning.
* Give the learner ownership of the process used to develop a solution.
* Design the learning environment to support and challenge learners' thinking.
* Encourage testing ideas against alternative views and alternative contexts.
* Provide opportunity for support and reflection on both the content learned and the learning process.

Teachers unfamiliar with PBL will profit from elaboration of the issues listed above. First, create an ill-structured problem based on desired outcomes, learner characteristics, and compelling situations from the real (relevant) world (Finkle and Torp, 1995). The ill-structured problem addresses one "big question or idea" in a "whole to part" form. The ill-structured problem must raise the concepts and principles relevant to the subject matter area, but data critical to the problem must not be highlighted. If critical data is highlighted the whole procedure then becomes a mere procedure of finding what the teacher deems essential, then feeding it back.

Brooks and Brooks (1993) state that learners of all ages are more engaged in problems addressed in "whole to part" forms. This structure allows for multiple-entry points and addresses multiple learning styles. Providing an overarching problem set also creates a purpose for engagement, as opposed to the usual assignment of a chapter and end-of-chapter study questions. Students know from the outset where they are headed and why (Savery and Duffy, In Press).

Relevance is a primary issue. Brooks and Brooks (1993) deem it one of the universal or guiding principles of constructivist teaching. They suggest searching for windows into students' thinking in order to pose problems of increasing relevance. The problem scenario should also challenge students' original hypotheses. The challenge, incongruity, anomaly, or discrepant event creates a springboard to activity based on cognitive dissonance (Keller, 1983). For example, Nussbaum and Novick (1982) state that in order for accommodation of a new concept to occur, students must first recognize a problem as well as their inability to solve it. Students' inability is brought about by presentation of a "discrepant event." A discrepant event is simply an inexplicable condition, statement or situation. The discrepant event creates a state of disequilibrium (or cognitive dissonance). The key in Nussbaum and Novick's argument is that once students are in a state of disequilibrium, they are motivated by "epistemic curiosity" (Berlyne, 1965) to reduce the disequilibrium. Nussbaum and Novick (1982) suggest that traditional instruction seldom provides for students to experience cognitive conflict. Bruce and Bruce (1992) suggest that logic-defying problems often make us feel disequilibrium. Motivation from the disequilibrium causes questioning, snooping, and searching to reduce uncertainty and re-enter a state of equilibrium.

**Execution** Finkle and Torp (1995) refer to the actual execution as "cognitive coaching." In this phase, students are actively defining problems and constructing potential solutions. Teachers will model, coach, and fade--supporting and making explicit students' learning processes. Students must be given time and stimulation to seek relevance and the opportunity to reveal their points of view. They also need time to ponder the situation or scenario, form their own responses, and accept the risk of sharing responses with peers (Brooks and Brooks, 1993). Using remote-sensing databases within ETE, students will be expected to synthesize and evaluate such matters as the cause and effect relationships of degradational and tectonic forces concerning the dynamic Earth and its surface; the relationship of atmospheric heat transfer to meteorological processes; and the relationship between Earth processes and natural disasters. Students should also be able to make and support insightful and informed recommendations to alleviate environmental problems.

Teachers and students used to traditional instruction may be in for some surprises. It takes time, patience and a willingness to accept risk and uncertainty to begin using these types of classroom methods. It may take teachers one to two years to feel confidence with these approaches to learning. Students, for example, will likely be very reluctant to take risks on their own--especially if they are used to having the objectives, assignments, and problems handed to them. If they are used to standard objective tests, then students may dwell more on what they have to do to "get their grade" than in readily adapting to the PBL format (Myers, Purcell, Little, and Jaber, 1993).

During the PBL process, teachers new to this technique, may be tempted to give students key variables, too much information, or problem simplification. Depending on the students' ages, complexity generates relevance and interest (Brooks and Brooks, 1993). Barrows (1992) states that teachers' interactions should be at the metacognitive level and that opinions or information sharing with students must be avoided. Doing so implies that there is a "correct answer" and takes away student ownership of the problem.

Student ownership is essential. If they do not own the problem, they spend their time figuring out what the teacher wants. One signal teachers and students will have to pay attention to is the presence of the dreaded "second question." In traditional lecture and recital classrooms teachers ask questions. A follow-up question to a student's reply usually sends the message that the answer was "incorrect." The student then spends more time trying to figure out "what the teacher" wants. Regularly asking students to elaborate sends the message that the teacher wants to know what the student thinks and why. Brooks and Brooks (1993) state that "awareness of students' points of view is an instructional entry point that sits at the gateway of personalized education...teachers who operate without awareness of their students' points of view often doom students to dull, irrelevant experiences, and even failure" (p. 60).

In a PBL classroom, teachers should act as metacognitive coaches, serving as models, thinking aloud with students and practicing behavior they want their students to use (Stepien and Gallagher, 1993). Students should become used to such metacognitive questions such as: What is going on here? What do we need to know more about? What did we do during the problem that was effective? Teachers coax and prompt students to use questions and take on responsibility for the problem. Over a period of time, students become self-directed learners, teachers then fade (Stepien and Gallagher, 1993).

**Summary** Our project, Exploring the Environment, is developing Earth Science modules for delivery over the Internet. Our position is that new technology such as remote sensing databases and electronic means of delivery are important tools that will create "wall-less" classrooms. Teachers' roles, however, may be the essential ingredient in effective technology use in the teaching-learning scenario. We have presented means for teachers to use in helping students engage in learning and reaching new levels of understanding. This paper reinforces the role of the teacher as the primary agent in successful teacher-student interactions. If anything, teachers' roles will become even more important. As Newman, Griffin and Cole (1989) state: "We have seen that the process of instruction cannot be reduced to direct transmission of knowledge, nor are creative learning processes necessarily entirely internal to individuals" (p. 112).

ETE students need time for exploring, making observations, taking wrong turns, testing ideas, doing things over; time for collaboration, collecting things, and constructing physical and mathematical models for testing ideas. They also need time for learning prerequisite mathematics, technology, or science they may need to deal with the questions at hand; time for asking around, reading, and arguing; time for wrestling with unfamiliar and counterintuitive ideas and for coming to see the advantage in thinking in a different way (AAAS, 1990). Teachers need time too--time to reclaim the skills of curriculum development and instructional creativity. Time and resources are needed for teachers to develop and deliver the ETE curriculum, to train and work together, to restructure the entire science classroom teaching practice to meet the diverse needs of students that comprise today's student body. To accomplish these vital tasks of staff development, the ETE Instructional Design Team will provide adequate time and funding for the kind of experimentation and risk taking needed to create motivating experiences for learners and teachers using contemporary science tools and topics to be successful in this new era of Science Education. (Botti and Myers, 1995) [[back to top]](http://www.cotf.edu/ete/teacher/teacherout.html#top)